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AUGUST 1976

**SUMMARY OF DEVELOPMENT AND RECOMMENDATIONS
FOR
A QUALITY ASSURANCE PROGRAM
FOR THE PROCUREMENT AND MANUFACTURE
OF
URBAN MASS TRANSIT OPERATING
EQUIPMENT AND SYSTEMS**

(NASA-CR-149559) SUMMARY OF DEVELOPMENT AND
RECOMMENDATIONS FOR A QUALITY ASSURANCE
PROGRAM FOR THE PROCUREMENT AND MANUFACTURE
OF URBAN MASS TRANSIT OPERATING EQUIPMENT
AND SYSTEMS Final Report (Jet Propulsion

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ACKNOWLEDGEMENT

Development of the guidelines for a quality assurance system and the associated recommendations necessitated achieving an awareness of, and a background in, the present practices and concerns of people and organizations presently making, buying, and using vehicles and train control systems in revenue service for Public transportation. To achieve this background, I visited many manufacturers and properties in the U.S. and Western Europe. However, due to time and cost constraints, I couldn't visit all. I, therefore, talked with several other properties and management firms by phone. I would like to thank each of them.

An important contribution to this report was made by Howard M. Weiss, consultant, who provided assistance in developing the guidelines and in acting as a sounding board on the recommendations.

A draft of the guidelines and recommendations was critiqued and commented on by many organizations and individuals, all most helpful and useful in finalizing the report.

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I. INTRODUCTION

The Transportation System Center (TSC) has been funded by the Urban Mass Transit Administration (UMTA), via Project Plan Agreement (PPA UM 529), to develop and implement a technical and management evaluation capability in the area of Safety and Systems Assurance.

Quality Assurance (QA) is one of the seven elements that comprise the Safety and System Assurance Program. The others are: Safety, Reliability, Maintainability, Security, Availability, and Life-Cycle Costing. The Jet Propulsion Laboratory (JPL) through the Department of Transportation Reimbursable Agreement No. RA 75-27 has been given the task of developing a recommended Quality Assurance program for the URBAN MASS TRANSPORTATION Industry and the management approaches thereto as a part of the foregoing TSC project.

A. OBJECTIVE

The objective of the JPL-UMTA QA task is to recommend to UMTA a viable quality program for the urban mass transit industry, and a management approach to ensure compliance with the program. Specifically this objective includes:

- RECOMMENDING FOR UMTA USE, A SET OF GUIDELINES FOR QUALITY ASSURANCE TO BE IMPOSED ON TRANSIT AUTHORITIES, AND A MANAGEMENT APPROACH TO ENSURE COMPLIANCE WITH THEM.
- RECOMMENDING A MANAGEMENT APPROACH TO BE USED BY THE TRANSIT AUTHORITIES (PROPERTIES) FOR ASSURING COMPLIANCE WITH THE QA GUIDELINES.
- RECOMMENDING QUALITY ASSURANCE GUIDELINES TO BE IMPOSED BY PROPERTIES AND UMTA FOR PROCUREMENT OF HARDWARE AND SYSTEMS.

The recommended *Quality* program and management approaches are based on the concept that a Quality Assurance Program is required to protect the interests of the transportation user and producer community from errors or misjudgment in technical and procurement activities. To the extent that the risks to the user interests are economically controllable through activities conducted before placing grant-funded transit elements in operation, appropriate quality assurance activities will be identified. In addition, interfaces to *Quality* were considered – for example, *Design and Development, Systems Engineering, Reliability, Safety, Test*, etc.

B. SCOPE

The Urban Mass Transit Industry is a very broad and complex field when one considers:

- (1) The many different kinds and levels of governmental and quasigovernmental agencies, and semipublic and private organizations involved, e.g. UMTA,

- individual state transportation departments, regional transportation districts, local transportation districts, transportation systems management/operating companies, consultants, manufacturers, contracting firms, etc.
- (2) The varied modes⁽¹⁾ of transit systems, e.g. *Buses* – small and large, *Moving Way*, *Light Guideway*, *Personal Rapid Transit (PRT)*, *Light Rail*, *Heavy Rail*
 - (3) The spectrum of facilities and hardware, e.g. bridges, tunnels, stations, fare boxes, escalators, power stations, tracks, vehicles, automatic train control, computers, radios, axles, motors, seats, brackets, anti-skid devices, etc.
 - (4) The varied degree of maturity of hardware design, manufacturing and operating experience
 - (5) The varied composition, activities, and location of manufacturers
 - (6) The extent and reliance on procurement of materials, parts, components, assemblies, subsystems, etc.
 - (7) The complexity of rail/guideway transit systems, e.g. facilities, equipment, and hardware.

Taking into consideration the foregoing, the study undertaken and the resulting recommendations are limited to the activities and organizations associated with the development, procurement, and manufacture of rail or guideway transit systems, buses, and to their critical or major components. We further limited the study and recommendations in respect to transit systems.

Each type of transit system includes a broad spectrum of facilities, equipment, and hardware, but they can be broken into four general categories (Fig. 1): FACILITIES, FACILITIES-INSTALLED EQUIPMENT (Service): FACILITIES-INSTALLED EQUIPMENT (Operation): and ROLLING STOCK. The prime emphasis (dotted line, Fig. 1) of this task was placed on the vehicle and train control aspect of the transit systems. We believe this is apropos from a safety, reliability, and system operational standpoint even though fixed facilities (construction) represents the vast bulk of *Capital Investment* dollars.

⁽¹⁾Ref. LEA Transit Compendiums for classification definition.

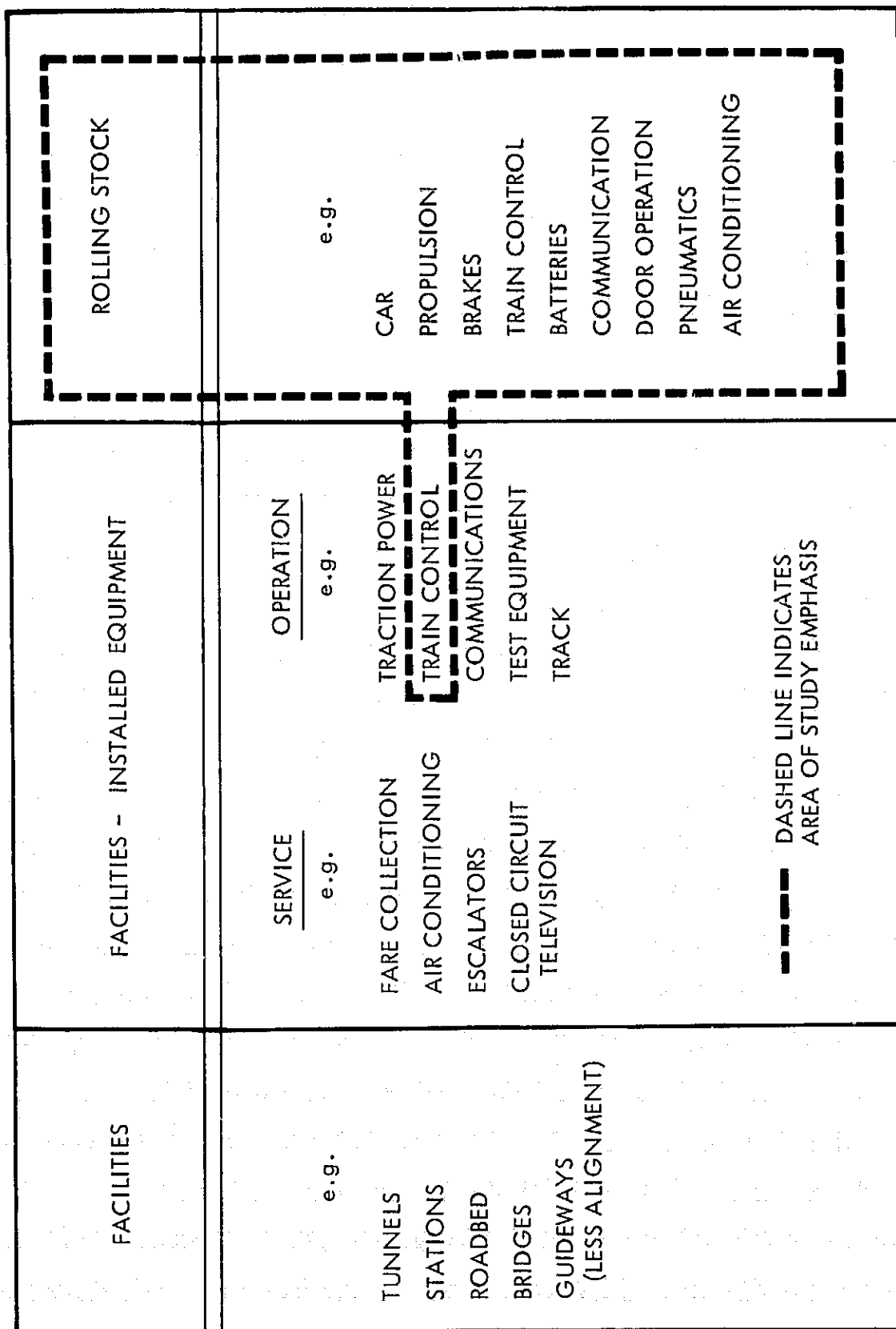


Figure 1. Transit System Composition

II. RECOMMENDATIONS

A. GENERAL

The urban mass transit industry makes, buys, and uses a wide range of hardware, components, vehicles, and technologies in providing public transportation. The buying and manufacturing experience of specific items varies between the many different properties and manufacturers.

The transit operator is concerned with maximizing operation and utilization of equipment in a safe and economical manner and with a minimum of maintenance and repair costs. The manufacturer of cost-competitive products is concerned with producing his product at the lowest possible cost to meet the buyer's specification with the emphasis on functional performance. Shortcomings in physical or functional attributes of the "delivered" product are sometimes corrected under a manufacturer's warranty. When compared to desired and expected operational life, this warranty is of a short duration. Shortcomings not covered by warranty are corrected by the transit operator.

Vehicles and train control systems are procured on a fixed-price contract awarded to the lowest priced "qualified" bidder. Major components and subsystems are often times procured as a noncompetitive "single" source procurement item due to design or other functional constraints. Hardware replaced, beyond the warranty period, as a result of failure, accident, or wearout, is generally procured (directly or indirectly) from the original equipment manufacturer. Therefore, the significance of the quality of the product becomes important as does the comparative quality of competing products.

It is recognized that "Quality" is a broad term that includes many facets other than inspection of the hardware. It encompasses many values such as passenger comfort, vehicle appearance — aesthetic things, operational reliability, cost, safety, ease and frequency of maintenance, conformance to technical requirements, etc. The overall quality system to be used must recognize these and accommodate them as part of its implementation. Additionally, other actions and requirements need to be imposed by disciplines other than *Quality Assurance/Quality Control* (e.g., *Design, System Engineering, Manufacturing, Safety, Reliability, Maintainability, Configuration Management*, etc.) in order to achieve "Quality".

The thrust of the recommendations is directed toward achieving a higher level of quality at a lower long-term cost both to buyer and seller by placing emphasis on early actions in the design and procurement stages; building it right the first time; and verifying that what is built is what is wanted.

Taking into consideration the foregoing factors, a set of recommendations and guidelines⁽²⁾ were prepared. Both general and detail recommendations are made. Where recommendations concern activities or actions primarily out of the scope (interfaces) of Quality Assurance itself, they are separately and only broadly identified and not discussed in any detail. Where organizational structure is a prime factor or driver, recommendations are of a general nature so as to allow for inclusion of different modes of implementation. Where there is a recommendation for UMTA to require the *Property* to do something, there is a corollary recommendation to the *Property* for its implementation.

⁽²⁾"Quality Assurance Guidelines for Application to, and Use by, Manufacturers of Rail/Guideway Vehicles, Buses, ATC, and their Major Subsystems" JPL Document 5040-34, August 1976.

General recommendations are presented in Section IIB and are in four parts:

- (1) *Management Actions for QA Program -- UMTA*
Actions required of UMTA to impose the QA system and to ensure compliance with it
- (2) *Transit Property Actions for QA Program*
Actions required of the properties (or UMTA when it is the buyer) to impose quality requirements and to ensure compliance with them
- (3) *Quality Assurance Guidelines for Procurements*
Guidelines for a QA system
- (4) *Interface Actions for QA Program -- UMTA/Properties*
Actions outside the scope of Quality Assurance that are required in order to achieve a quality product.

The recommended quality requirements to be imposed on manufacturers are referenced in Section IIB.3. The recommendations are detailed, where apropos, in Section IIC.

NOTES:

- (1) The QA Guidelines Document (Document 5040-34) is being reviewed for applicability of detail for bus procurements. If sufficient modification is required, it shall then be prepared as two separate documents. This determination will be made subsequent to the Industry Workshop.
- (2) Implementation of the "Interface Action Recommendations" are not a prerequisite for implementing the recommended actions for the Quality Program and Quality Assurance Guidelines.

B. GENERAL RECOMMENDATIONS

1. MANAGEMENT ACTIONS FOR QA PROGRAM -- UMTA

- (a) IMPOSE QUALITY SYSTEM AND MANAGEMENT REQUIREMENTS IN GRANTS AND IN UMTA PROCUREMENTS
- (b) IMPOSE REQUIREMENT FOR SOURCE INSPECTION OF PROCURED HARDWARE
- (c) PROVIDE FOR UMTA REVIEW TO ENSURE INCORPORATION OF QUALITY AND INTERFACE REQUIREMENTS IN PROCUREMENT DOCUMENTS (see details in II.C.1.a)
- (d) PROVIDE THIRD PARTY QUALITY ENGINEERING AND INSPECTION SUPPORT TO PROPERTIES (see details in II.C.2. and II.C.4.b.)
- (e) PROVIDE QUALITY ENGINEERING AND INSPECTION SUPPORT TO UMTA PROCUREMENTS (see details in II.C.1.a.)
- (f) ESTABLISH A SYSTEM TO DETERMINE AND IDENTIFY ACCEPTABLE MANUFACTURER'S QUALITY/INSPECTION SYSTEMS

2. TRANSIT PROPERTY ACTIONS FOR QA PROGRAM

- (a) DEFINE AND IMPLEMENT A MANAGEMENT ORGANIZATION SYSTEM THAT PROVIDES FOR: ENSURING THE INCLUSION OF HARDWARE AND QUALITY REQUIREMENTS INTO PROCUREMENT DOCUMENTS, PROCUREMENT FROM APPROVED/QUALIFIED SOURCES, INSPECTING AND ACCEPTING THE HARDWARE AND/OR TRANSIT SYSTEM (see additional detail in II.C.3)
- (b) ESTABLISH REQUIREMENTS FOR A QUALITY SYSTEM IN THE PROCUREMENT DOCUMENTS BY REFERENCING THE "QA GUIDELINE DOCUMENT" (JPL DOCUMENT 5040-34)
- (c) ESTABLISH HARDWARE (E.G. WORKMANSHIP, PERFORMANCE, ACCEPTANCE, AND OTHER TECHNICAL CRITERIA) QUALITY REQUIREMENTS IN TECHNICAL DOCUMENTS USED FOR PROCUREMENT
- (d) ESTABLISH INTERFACING MANAGEMENT (E.G., DESIGN, TEST, RELIABILITY, SAFETY, ETC.) SYSTEM AND TECHNICAL REQUIREMENTS IN PROCUREMENT DOCUMENTATION
- (e) PROCURE SYSTEMS AND HARDWARE FROM APPROVED AND/OR QUALIFIED SOURCES
- (f) PERFORM SOURCE INSPECTION OF PROCURED HARDWARE/SYSTEMS (see details in II.C.4)
- (g) ESTABLISH A REQUIREMENT FOR SUBMITTING WITH EACH SEALED BID (RAIL, GUIDEWAY, ATC) A QUALITY ASSURANCE PROGRAM PLAN AND OTHER REQUIRED MANAGEMENT OR TECHNICAL PLANS. THESE MUST BE NEGOTIATED AND APPROVED BY THE PROPERTY PRIOR TO BID SUBMITTAL.
- (h) ESTABLISH A REQUIREMENT FOR SUBMITTING WITH EACH SEALED BID (BUSES, MAJOR COMPONENTS, SUBSYSTEMS) A DESCRIPTION OF THE QUALITY ASSURANCE AND INSPECTION SYSTEM, OR A CERTIFICATION FROM THE THIRD PARTY INSPECTION SERVICE SHOWING THAT THE SYSTEM IS ACCEPTABLE AND APPROVED.
- (i) ESTABLISH REQUIREMENT FOR SUBMITTING WITH EACH SEALED BID A MANUFACTURING FLOW PLAN, WHICH MUST BE NEGOTIATED AND APPROVED BY THE PROPERTY PRIOR TO BID SUBMITTAL (see II.C.6 for details)
- (j) AS A MINIMUM, PROCUREMENT DOCUMENTATION, INCLUDING TECHNICAL AND QUALITY REQUIREMENTS, MUST BE SUBMITTED TO UMTA FOR REVIEW WITH EACH GRANT REQUEST

- (k) THE PROPERTY SHALL SUBMIT TO UMTA A DESCRIPTION OF ITS IN-HOUSE QUALITY ASSURANCE PROGRAM WITH ITS APPLICATION FOR A HARDWARE OR TRANSIT SYSTEM GRANT. THEREAFTER ONLY MAJOR CHANGES NEED TO BE SUBMITTED WITH SUBSEQUENT GRANT REQUESTS.

3. QUALITY ASSURANCE REQUIREMENTS FOR PROCUREMENTS

- (a) A QUALITY ASSURANCE SYSTEM RATHER THAN AN INSPECTION SYSTEM IS RECOMMENDED FOR APPLICATION TO VEHICLE, AUTOMATIC TRAIN CONTROL, AND OPERATIONAL AND SAFETY CRITICAL VEHICLE COMPONENTS

IT IS RECOMMENDED THAT THE PROPERTY AND THE MANUFACTURER IDENTIFY THE CRITICAL ITEMS.

- (b) IT IS RECOMMENDED THAT THE INTERFACE REQUIREMENTS OF THE QA SYSTEM BE INTEGRATED WITH THE OTHER TECHNICAL AND MANAGEMENT REQUIREMENTS E.G., DESIGN REVIEW, CONFIGURATION MANAGEMENT, TEST, RELIABILITY, ETC. WHEN THEY ARE DEFINED IN A PARTICULAR PROCUREMENT.

- (c) IT IS RECOMMENDED THAT THE REQUIREMENT FOR QUALITY ASSURANCE BE SPECIFIED IN THE PROCUREMENT DOCUMENTS, E.G.:

"THE MANUFACTURER SHALL BE REQUIRED TO IMPLEMENT A QUALITY ASSURANCE PROGRAM IN ACCORD WITH THE REQUIREMENTS OF JPL DOCUMENT 5040-34"

- (d) IT IS RECOMMENDED THAT THE QA SYSTEM GUIDELINE DOCUMENT (JPL DOCUMENT 5040-34) BE USED IN LIEU OF REWRITING QUALITY SYSTEM REQUIREMENTS FOR EACH AND EVERY PROCUREMENT.

- (e) IT IS RECOMMENDED THAT THE EQUIPMENT SPECIFICATION INCLUDE ALL DETAIL HARDWARE RELATED QUALITY REQUIREMENTS. THESE SHOULD INCLUDE BUT ARE NOT LIMITED TO:

SPECIFIC TEST REQUIREMENTS AND ACCEPTANCE PARAMETERS; SPECIFIC HARDWARE WORKMANSHIP LEVELS WHEN REQUIRED; APPLICABLE CODES, REGULATIONS OR RELATED REQUIREMENTS; DELIVERABLE DATA REQUIREMENTS; WARRANTY REQUIREMENTS; PERFORMANCE AND PHYSICAL REQUIREMENTS; ACCEPTANCE CRITERIA AND LOCATION; ETC.

4. INTERFACE ACTIONS FOR QA PROGRAM – UMTA AND PROPERTIES

- (a) IDENTIFY APPLICABLE SAFETY, RELIABILITY, MAINTAINABILITY, AND TEST REQUIREMENTS AND IMPOSE THEM IN THE PROCUREMENT DOCUMENTS
- (b) CONTRACTOR SELECTION SHOULD INCLUDE EVALUATIONS OF MANAGEMENT INCLUDING QUALITY ASSURANCE APPROACHES; TECHNICAL CONSIDERATIONS; AND LONG TERM COST EFFECTIVENESS (see details II.C.5)
- (c) PROVISION SHOULD BE MADE FOR MANUFACTURING AND TESTING OF A *PROTOTYPE* BEFORE AWARDING A PRODUCTION CONTRACT FOR NEW DESIGN VEHICLES, TRAIN CONTROL SYSTEM, OR SIGNIFICANT OR CRITICAL COMPONENTS
- (d) ESTABLISH A TEST PROGRAM GUIDELINE TO DEFINE BASIC TEST REQUIREMENTS. IT SHOULD DEFINE: ALL LEVELS OF HARDWARE THAT REQUIRE TEST (E.G., PARTS, COMPONENTS, SUBASSEMBLIES, ASSEMBLIES, SYSTEMS, ETC.); AND TYPES OF TEST APPLICABLE (E.G., QUALIFICATION, IN-PROCESS, ENVIRONMENTAL, HARDWARE AND COMPONENT ACCEPTANCE, ASSEMBLY LEVEL, SYSTEM LEVEL, END-ITEM ACCEPTANCE, ETC.)
- (e) PROVIDE FOR AN INDUSTRY-WIDE FAILURE REPORTING AND DATA DISSEMINATION SYSTEM
- (f) ESTABLISH A DESIGN REVIEW PROGRAM FOR NEW VEHICLES AND/OR SUBSYSTEMS AND SIGNIFICANT CHANGES TO EXISTING DESIGNS
- (g) ESTABLISH A SYSTEM FOR QUALIFYING AND IDENTIFYING QUALIFIED SOURCES FOR SAFETY AND OPERATIONALLY CRITICAL EQUIPMENT
- (h) ESTABLISH A SET OF REQUIREMENTS AND/OR GUIDELINES FOR INTEGRATION RESPONSIBILITIES AND METHODOLOGY, AND SYSTEM ENGINEERING TO SUPPORT DEVELOPMENT, PROCUREMENT, INSTALLATION, AND CHECKOUT OF COMPLEX OR LARGE TRANSIT SYSTEMS, E.G., RAIL, GUIDEWAY
- (i) REQUIREMENTS AND GUIDELINES FOR CONFIGURATION MANAGEMENT SHOULD BE DEVELOPED AND IMPLEMENTED
- (j) ESTABLISH A SYSTEM AND SAFETY ASSURANCE REVIEW PROGRAM FOR NEW RAIL AND GUIDEWAY SYSTEMS AND FOR MAJOR ADDITIONS OR CHANGES TO EXISTING SYSTEMS
- (k) INITIATE A STUDY OF QA PRACTICES AND REQUIREMENTS APPLIED TO TRANSIT PROPERTY'S OPERATIONAL AND MAINTENANCE PHASES

C. DETAIL RECOMMENDATIONS

Some of the general recommendations made in Section II are expanded in here and include those relating to in-house UMTA QA actions; the use of third-party Quality Engineering and Inspection support; source inspection by the property; and contract award approach.

1. IN-HOUSE UMTA QA SUPPORT ACTIONS

(a) *UMTA should provide for a small in-house Quality Engineering activity.*

- It should provide support to in-house programmatic activities in determining the need and appropriateness of Quality requirements for R&D Prototype and Demonstration projects.
- It should provide for evaluating quality programs to be implemented by operating properties for new and/or major system additions.
- It should provide policy and technical direction to the third-party Quality Engineering and Inspection Support activity.

(b) *Review of Grant Request Support Material*

UMTA should verify that technical/contractual documents submitted for Guideway, Rail Vehicle, or Train Control procurement grants contain:

- Provisions for source inspection by the property.
- Requirement for the manufacturer to have a quality system in accord with the requirements of JPL Document 5040-34.
- Workmanship requirements are specified or referenced.
- A requirement for the submittal, with the manufacturer's bid, of a manufacturing flow plan including identification of the manufacturer's inspection station and inspection points, and showing test activities.
- A requirement for the submittal of the manufacturers' (guideway or rail vehicles and train control) quality assurance program plan, and other required plans, with the proposal.
- Description of how source inspection is to be accomplished.
- "Acceptance" location, and requirements are defined in the Specification.
- Requirements are imposed for safety, reliability, parts materials and process control, and configuration management programs.
- The methodology of performing on-site vehicle acceptance and system acceptance shall be defined.

UMTA should verify that technical/contractual documents submitted for Bus or for Vehicle Component procurements grants contain:

- Provisions for source inspection by the property
- Description of how source inspection is to be accomplished
- Workmanship requirements are specified or referenced in the technical document
- Requirement for the manufacturer to have an inspection/quality system in accord with the requirements of JPL Document 5040-34

- Quality/Inspection System is to be approved prior to property signing of contract
- A requirement for the submittal, with the Manufacturer's bid, of a manufacturing flow plan, including identification of the manufacturer's inspection stations and inspection points, and showing test activities
- "Acceptance" location and requirements are defined
- A plan for accepting and fitting-out (for service) the procured vehicles when the number of vehicles procured exceeds 20% of the existing fleet or 25 vehicles (whichever is the smaller number). It shall also include the impact to the regularly scheduled workload, and the staffing necessary to accomplish both the acceptance and maintenance workloads.

2. THIRD PARTY QUALITY ENGINEERING AND INSPECTION SUPPORT

UMTA should provide for and fund an organization separate from transit manufacturers or operating properties, preferably through a nonprofit organization, to perform an ongoing product support Quality Engineering and Inspection service.

- It should provide for resident quality engineering and inspection at major bus [Fig. 2(a)] manufacturers to ensure a continuum of baseline quality system assurance and a uniform level of product quality assurance for a progression of changing UMTA-sponsored customers within a particular facility. Figure 2 shows why usage of this support is needed at bus and major vehicle component manufacturers and not at rail/guideway [Fig. 2(b)] manufacturers.
- It should provide for quality engineering support and inspection services on an itinerant, and periodic evaluation basis for other bus and vehicle component manufacturers wherein full-time coverage is not needed [Fig. 2(c)].
- It should provide for assistance to properties in evaluating manufacturers' proposed quality systems.
- It should provide for auditing and validating manufacturers' quality assurance and inspection systems.
- It should provide for additional quality engineering and inspection support services to UMTA programs and for hardware procurements wherein UMTA is the funding sponsor and hardware recipient/owner.
- It should provide for assistance in resolving generic vehicle and component quality problems that may be encountered frequently with equipment acquired with UMTA financial sponsorship.

These activities would not abrogate a property's right to determine the final quality level of the specific product but would provide a baseline to help the manufacturer hold down his "present costs" from arbitrary rejections and subsequent cost increases to future UMTA-funded buyers.

A property that has its own inspection staff would retain the right to provide its own resident inspectors if it so chooses. In this event, the "third-party" inspection service would provide support to the property's inspector, but would still be responsible for ensuring that the level of quality does not degrade. The general manager of the procuring property is the final authority on disagreements between the two inspection activities.

MAJOR BUS MFG

- MANY BUYERS - (A THRU H)
- ORDER SIZE VARIES
- CONTINUOUS PRODUCTION
- SOME REPEAT BUYS
- PROPERTY SIZE VARIES
- INTERMITTENT/NONEXISTANT PROPERTY INSPECTION
- CAPTIVE LINE
- LARGE NUMBER OF DIFFERENT CUSTOMER INSPECTORS - COMING AND GOING

PROPERTY INSPECTIONS

- ① FIRST VEHICLE INSPECTION
- ② RANDOM INSPECTION
- ③ FINAL INSPECTION - VEHICLE

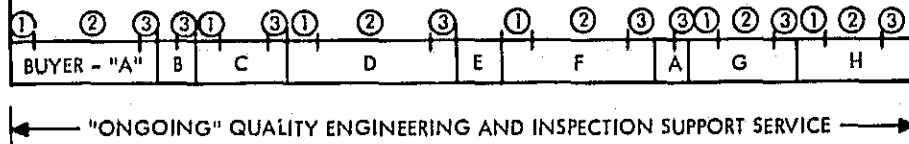


Fig 2(a)

GUIDWAY/RAIL VEHICLE MFG.

- FEW BUYERS - (A THRU C)
- LONG-TERM CONTRACTS
- FEW REPETITIVE BUYS
- INTERMITTENT PRODUCTION
- RELATIVELY CONSTANT CUSTOMER INSPECTION FORCE

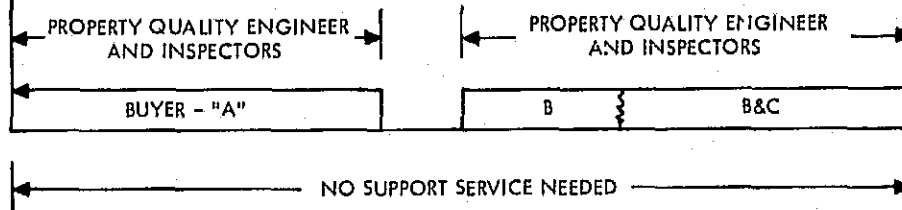


Fig 2(h)

MAJOR/CRITICAL COMPONENT MFG

- MANY BUYERS (A THRU N)
- CONTINUOUS PRODUCTION
- GENERALLY NO PROPERTY INSPECTION
- SOME VEHICLE MFG INSPECTION
- VARYING ORDER SIZE
- VARYING PRODUCT
- NEW PRODUCT

PROPERTY INSPECTION (AS DESIRED)

- ① MAJOR PROBLEM
- ② NEW PRODUCT

"SUPPORT" INSPECTION

- ① RANDOM - CONTINUOUS PRODUCTION
- ② PERIODIC
- ③ FIRST ARTICLE - NEW PRODUCT/SIGNIFICANT DESIGN CHANGE

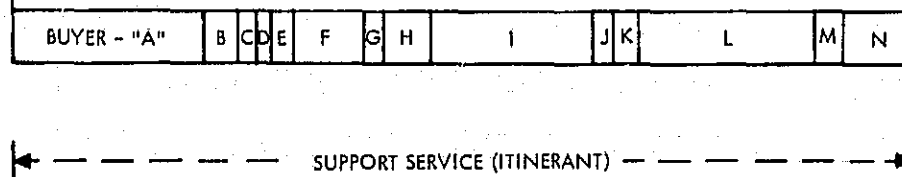


Fig 2(e)

Figure 2. Support Service-Property Inspection Usage and Inter-Relationship

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A projected work load split of the "third-party" support between the activities -- major manufacturers, other manufacturers, and general support/generic problems could be typified by the following table:

| | | |
|---------------|---------------|------------------|
| 50% | 25% | 25% |
| MAJOR | OTHER | SUPPORT/PROBLEMS |
| MANUFACTURERS | MANUFACTURERS | |

3. TRANSIT PROPERTY -- ORGANIZATIONAL STRUCTURE

No specific organizational structure is required. However, the person responsible for Quality Assurance and the individuals performing inspection shall have the organizational freedom and placement to independently assess and inspect without undue influence.

New rail or guideway programs at properties should have a Quality Assurance element established early in the program, preferably before initiation of design. It should be placed in the organization at a reporting level at least equal to engineering, procurement, and operations.

4. TRANSIT PROPERTY SOURCE INSPECTION

(a) Required

- Properties must provide for source inspection at vehicle and train control manufacturers.
- Properties must require proof of inspection and acceptance by the vehicle or component manufacturer for critical, safety related, high value, or operationally significant components.
- Properties should provide source inspection at manufacturers of major or critical vehicle components when bought directly by the property, and that are of a new design or are to be provided to a vehicle manufacturer for his installation into a vehicle being procured by the property.

(b) Staffing

Inspection should be made, preferably by property's own personnel for rail or guideway vehicle, and ATC procurements, and third-party support for other procurements.

- Inspection personnel
- Senior/lead maintenance personnel if bus property does not have an inspection function and third-party support service is not provided.
- Personnel doing inspection and acceptance should have independent access to property general management, and organizationally should not be part of the procurement function.

- Technical direction of inspection personnel performing work on rail or guideway vehicle, or train control procurements should be by a quality engineer employed by the property.

When a property is insufficiently staffed to perform its own inspections:

- It must contract from a qualified organization for inspection services at rail, guideway, ATC manufacturers
- It must obtain services of the third-party quality engineering and inspection support contract for inspection at other manufacturers, or contract with a qualified organization if the third-party support is not provided.

(c) *Activity*

- Source inspection (including first article) shall be performed at various stages of fabrication, assembly, and test. All features/characteristics that are defined by the property as requiring inspection by the customer shall very specifically be inspected and validated. All other activities shall be randomly inspected to ensure compliance by the manufacturer. Emphasis shall be placed on areas of assembly that will be hidden from view by subsequent manufacturing actions, on items that are critical to safety, maintenance, or operation and/or features that have highly visible aesthetic effect.
- An inspector shall be resident in the manufacturer's facility to verify and inspect the fabrication, assembly, test, and workmanship acceptance of the first vehicle or system being procured on that order.
- He will audit and validate the implementation of an acceptable Quality Assurance/inspection system, unless this is being provided for by resident third-party Quality Engineering support.

5. CONTRACT AWARD

The present method of contract award approach should be modified.

- Procedures and criteria should be established for evaluating management aspects and technical considerations in proposals.
- Results of the management and technical evaluations should be factored into the award determination such that "Low Bid" is not the prime and/or only determining award factor for major procurements.

"Product Quality, and lowest overall cost" are not necessarily achieved by the lowest bid. Consideration should be given to technical problem resolution, technical approach, manufacturing approach, reliability, maintainability, life cycle costing, safety considerations and solutions, quality system approach, warranties, etc. The "best product at the lowest cost for the expected life of the product" should be the prime factor in determining contract award.

6. MANUFACTURING FLOW PLAN SUBMITTAL

- For procurements of hardware or systems that are not presently in production and wherein the manufacturing flow, processing, sequencing, etc., are not firmly established, the manufacturing flow plan submitted with the bid shall be updated and approved by the property before the start of production.
- Changes in manufacturing that are deemed necessary to be implemented during the contract that do not degrade product quality, preclude inspection, or affect contractual requirements may be made. However, the customer shall be notified prior to implementation and the changes shall be subject to his review with right of disapproval.
- The manufacturing plan shall depict the sequencing and flow of fabrication, assembly, and test. It shall also include inspection points and reference to applicable process specifications, test procedures, etc.

III. BACKGROUND

A. GENERAL

The development of recommendations and guidelines appropriate to the procurement and manufacture of vehicles, train control systems, and their components necessitated an understanding of:

- "Who" are the operators and buyers of vehicles and systems
- "What" kinds of vehicles and systems are procured and used
- "How" are they procured
- "How" does the buyer assure he receives "What" he ordered
- "Who" produces these vehicles, systems, and their components
- "How" does the manufacturer control and ensure that what the buyer ordered is what he receives

This was achieved by conducting a literature search, trade publication reviews, and visiting or talking with various manufacturers, transit properties, a consultant firm, property management companies, and a state agency. Tables 1 (Properties) and 2 (Manufacturers) list those organizations contacted or visited.

Before finalization of the guidelines and recommendations, it was believed necessary to involve the potential using industry in assessing them. As a result, a draft copy was sent to 100 organizations and people for their critique and comment. This covered a broader spectrum than I was able to personally contact. Responses were received from 40 recipients. Their suggestions and comments were reviewed and, as appropriate, incorporated into the guideline and recommendations.

It was intended to have a workshop wherein various members of industry would be invited to discuss the above comments, guidelines, and recommendations before finalization. However, due to time constraints and other factors, it was not possible to do this. It is suggested that a workshop be held prior to final submittal of the documents to UMTA by TSC.

The assistance of industry, from both an informational and critique standpoint, was most helpful. It is interesting to note that there is a wide variance in what buyers want and expect in the way of quality, and how sellers arrive at a delivered quality level. There are two threads that seem to flow through both parties and they are "function and appearance," and "lowest cost." Each of these two threads are seen differently at the same time by the "Buyer" and the "Seller."

There are other active forces in play that result in finally affecting the foregoing. The present thrust of expanding the availability of transit vehicles for use, and the types of vehicles or systems to be used has resulted in new "buyers" entering the market, and manufacturers entering and leaving the market place. The source of funding and the requirement for competitive low-bid fixed-price procurements is impactive. The interactive affect of manufacturer performance, and the buyer's penalty clauses on a specific contract have an effect in relation to the quality and costs of subsequent procurements by other buyers.

Table 1. Property Contacts

| CITY | PROPERTY | OTHER |
|-----------------|-------------------------------|----------------------------------|
| Atlanta | — | PBTB |
| Atlanta | MARTA | |
| California | — | CALTRANS |
| Cleveland | CTS | |
| Denver | RTS | |
| Jacksonville | Jacksonville Trans. Authority | |
| Los Angeles | SCRTD | |
| Munich, Germany | Munich Stadtwerke | |
| New York | NYCTA | |
| Oakland | ACTD | |
| Paris, France | R.A.T.P. | |
| Philadelphia | SEPTA | |
| | PATCO | |
| | City of Philadelphia | |
| San Francisco | SFMR | |
| | GGBHTD | |
| Seattle | Metro | |
| | (various) | ATE Management & Service Company |
| | (various) | ATC (American Transit Corp.) |

Table 2. Manufacturer Contacts

| EQUIPMENT | COMPANY | EQUIPMENT | COMPANY |
|-------------------------------------|---|---------------------|--|
| Heavy Rail | Boeing — Vertol Duwag Pullman-Standard Swiss Industrial Group (SIG) Winder (Rohr) | Buses — Large | AM — General Bus and Car Flexible GMC Truck and Coach M.A.N. |
| Light Rail | Boeing — Vertol Duwag SIG | Buses — Articulated | Bus and Car M.A.N. |
| ATC (automatic train control) | GRS Siemens Union Switch & Signal | Buses — Midi/Small | FMC Daimler — Benz Transcoach |

The mix of manufacturers is changing wherein there are new companies and/or ones new to the urban transit scene entering the market place while old-line companies are departing. Included within this mix/change is the expanding inclusion of manufacturers in Europe, Japan, South America, and Canada.

B. PROPERTIES

There is a large variation in types, size, and structure of organizations guiding, providing, or regulating urban mass transit. Actions, activities, responsibilities, and authority, in turn, vary dramatically. They include State organizations e.g. Caltrans, Michigan Department of Transportation; Regional organizations e.g., Bi-State Development Agency, Regional Transportation Authority; Metropolitan organizations e.g., MARTA, SCRTD, MTA; Local organizations e.g. NYCTA, Chapel Hill Community Transit.

The vast majority of transit operators are now public agencies and very few are private. The funding for new vehicles and systems is virtually all "Public" money, with the majority (approximately 80%) of the money being provided by the Federal Government through UMTA.

Most of the properties buying vehicles and systems are new to the present marketplace. They either have not bought vehicles for several years, or they are instituting a service or placing into service vehicles or systems that are new to their operation, or are newly created properties. The quantity of vehicles being procured by one buyer can vary from a few to several hundred.

There are new vehicles and systems, including components, being introduced into revenue service. Entirely new transit systems are being implemented, e.g., MARTA and WMATA; and Airtrans. New vehicles (in addition to the foregoing) are being added to existing systems, e.g., SLRV for MBTA and SFMR; articulated buses for SCRTD, Seattle, Chicago, etc; new components and features are being introduced, e.g., antiskid, air conditioning, wheelchair lifts, etc.

There are consortiums of various properties being put together in order to procure some of the new vehicles, e.g., Articulated buses, and the "Interim" bus.

Properties are concerned with the quality of the product they receive from the manufacturer. These concerns include but are not limited to performance, reliability, maintainability, and aesthetics. The form of concern is expressed in several different ways. Warranty and delivery/performance penalty clauses are considered a "must." Many people feel the manufacturer relied too heavily on "fix it under the warranty" rather than doing it right during production or fixing it before delivery. In order to get the quality they want in the vehicle, many properties feel they have to specify, in great detail, the specific parts, materials, processes, components and associated manufacturers, etc. They base these details on their own operational and maintenance experience.

When they specify an item, they allow for "an equivalent," but it is up to the bidder to justify and prove the "equivalency." Specifications vary drastically in content and their callout of workmanship, inspection, test, and performance. They vary from very detailed to very general. The third mechanism that many properties use to obtain quality is to have someone inspect the vehicles while they are being built at the manufacturers. The extent of this varies from placing a man (sometimes several) in residence from just before start of production until the last delivery; to having no one visit the plant. Generally it is the smaller property that fits the latter category.

Only a few of the largest properties have their own inspection organization. Several use their senior or lead maintenance personnel for this function, while others hire consulting firms to provide inspection service for them. There is some communication between various sets of properties (depending on location, personal contacts, etc.) as to maintenance problem, equipment failures or manufacturing problems. It is worthy to note that American Public Transit Association (APTA) has a subcommittee working on developing a failure reporting system for rail systems, and that CALTRANS is also looking at a failure reporting system for bus operations in California.

In contrast to the U.S. properties practice of awarding contracts on a "low bid" winner basis, properties in Europe grant contracts on an evaluation that includes technical considerations as well as cost. They also tend to have their own inspection organizations who inspect not only the assembly of the vehicles, but also the assembly of major components, e.g., engines — when these were being procured directly by the property and furnished to the vehicle manufacturer. They have specific (mandatory) inspection points as well as general ones, with the specific ones called out in flow plans.

Quality Plans and other management and technical plans required in rail vehicle procurements are being submitted after the contract has been signed. This has sometimes caused problems. Contractors have bid (fixed price) with certain approaches in mind which turn out to be different from the buyer's expectations and understanding. It should be noted that at least one property in procuring buses required a definition of the manufacturers' quality program via a Quality Plan before the contract was awarded.

C. MANUFACTURERS

The perceived result of *Quality* by the manufacturer is the concept of "*Does it function;*" if so, "*it's good.*" This in itself forms a dichotomy. The manufacturer wants the buyer to specify less detail and restrain himself to specifying only performance, while the buyer is concerned with ensuring that what he receives not only "works," but looks like what he wants, meets his performance needs, and will last for the expected life at a reasonable initial and overall cost.

The various manufacturers have recognized a need for inspecting their product during fabrication, assembly, and before it goes "out the door." The majority of manufacturers have an inspection organization to perform this function, generally independent of the organization performing the work itself. In some cases, a skilled worker or a motivational self-inspection approach is employed. Some companies are using or are in the process of adding a quality engineering function to their operations.

The degree of implementation of inspection and quality control functions vary significantly between companies. There are however some broad generalizations as to the inspection activities and their present implementation that can be made.

- (1) Inspection/quality control systems are not generally defined.
- (2) Many of the "Key" quality control personnel are relatively new in their present position.
- (3) There are very few quality engineers, and the ones being used are generally in newly created positions. Interestingly, the use of quality engineers seems to be increasing.

- (4) Design and industrial engineering personnel are in many cases remote from the facility implementing the design, and inspection personnel have little or no direct interface.
- (5) Most functional and many fabricated items are procured from other manufacturers.
- (6) The assembly lines for vehicles are generally captive lines devoted to the production of vehicles for the urban mass transit industry.
- (7) Design definition is via engineering drawings and specifications. The use of part numbers, and in the case of major functional items serialization is a common practice. In some companies, hardware, components, or circuitry critical to operation/safety are identified as such on the drawings and in one case, the hardware and planning.
- (8) Manufacturing planning and sequencing is a normal function. The range of detail is more comprehensive in some companies than in others. It varies from primarily a Production Control use to a detailed set of instructions.
- (9) Process definition and workmanship criteria are generally lacking or ill-defined and are usually left to the discretion of the individual doing the work or judgement of the individual accepting the work.
- (10) Receiving Inspection of procured items varies very significantly. In some facilities, it is barely more than a "count and damage." In another, all items are inspected on an established sampling plan, with all critical items being 100% inspected and all functional items tested for acceptability before installation in the vehicle. However, functional items received at most companies are generally not tested until they are installed and tested as part of the vehicle. Great emphasis is placed on the "integrity" of the supplier, and that if it doesn't work, "replace it at the vehicle level." Vendor fabricated items made to the buyer's tooling generally receive inspection coverage of some type, e.g. (either source, first article, or some level of detail verification at receipt).
- (11) Source inspection is relatively limited by the bus manufacturers and is more predominant in the rail area — although this varies.
- (12) First Article inspection of items coming off jigs and fixtures is generally accomplished, as is control of the tooling. Tooling control varies within companies.
- (13) Inspection and acceptance of fabricated parts is generally accomplished. Inspection of assembly activities are on an overview/patrol basis. In production line activities, there are no mandatory inspections.
- (14) Definition of what is to be inspected and verified is generally informally defined. There are however many instances of inspection instructions or check-lists. These vary from company to company, and sometimes between inspection stations within the same company as to availability and content.
- (15) Control, processing, and handling of nonconforming hardware is generally not defined.
- (16) Final inspection and test are generally to check lists and/or procedures. In-process or other levels of testing are generally not defined nor controlled.
- (17) Calibration of measuring and testing equipment varies from company to company as to what it comprises, how it is controlled, and if it is to be accomplished.
- (18) Some companies are performing an independent audit of their completed vehicles.